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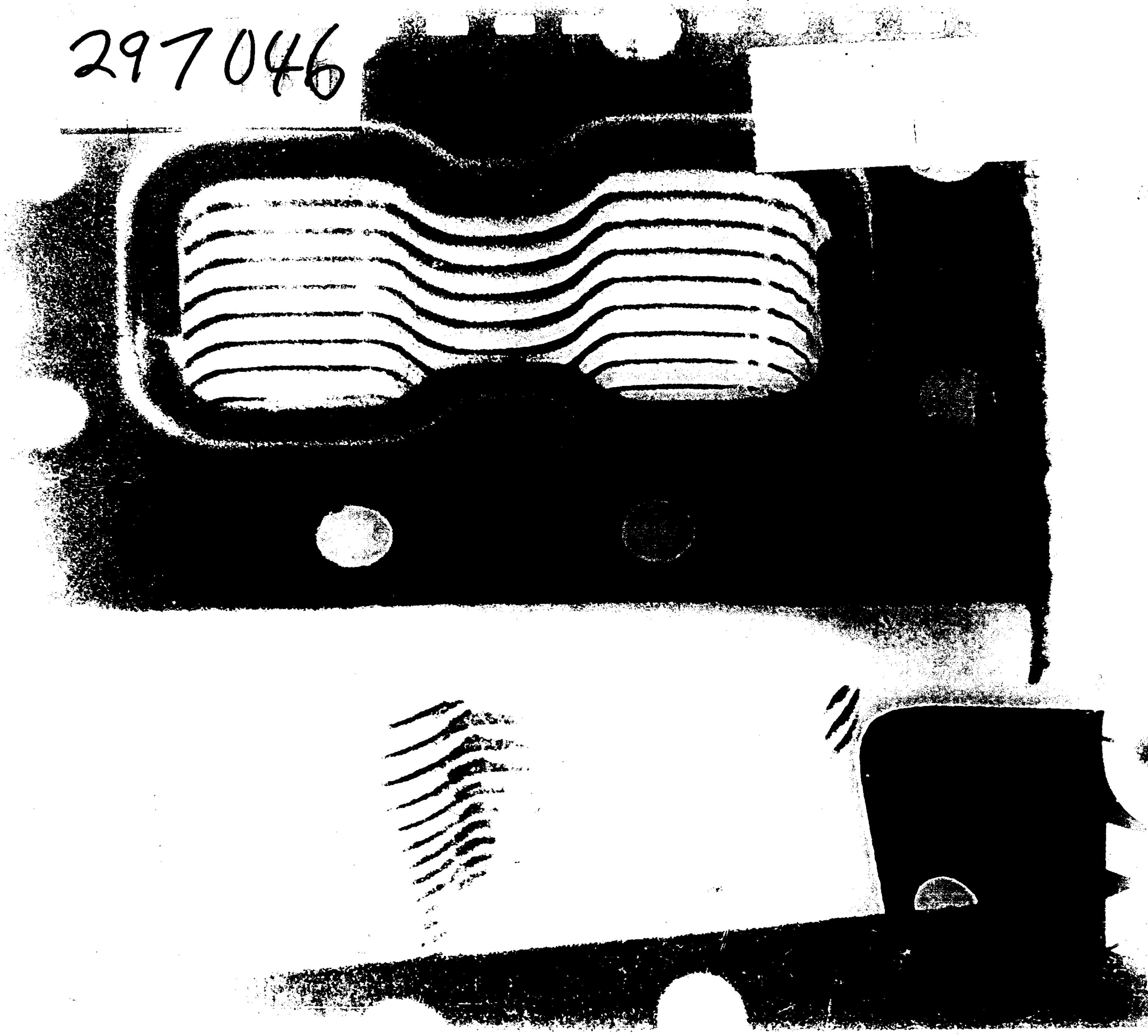


INTERIM DEVELOPMENT REPORT

for

AN IMPROVED BROADBAND, LOW-LOSS TRANSMISSION LINE SYSTEM TO BE INSTALLED WITHIN A RETRACTABLE SUBMARINE MAST

This Report covers the period November 1, 1962 to December 31, 1962

AIRTRON, a division of Litton Industries

Morris Plains, New Jersey

NAVY DEPARTMENT BUREAU OF SHIPS ELECTRONICS DIVISIONS

CONTRACT NO. NObsr-87676

PROJECT SERIAL NO. SS-021001, Task 9025

WRITTEN BY: Edward S. Hensperger
Engineering Product Manager

APPROVED BY: Ernest Wantuch, Ph. D
Vice President,
Director of Engineering

DATED: February 21, 1963

Airtron, a division of Litton Industries

ABSTRACT

This report covers the second interim phase of the contract to develop an improved transmission line system for use in the ECM mast of a submarine.

During this period of the contract, a purchase order for the ALB-134 ridge waveguide was issued to Standard Metals Corporation for delivery by the end of March. The splinaline coaxial line on order from Precision Tube Corporation was scheduled for delivery early in December, but delivery has not yet been made.

An "end fire" version of the ALB-134-to-coaxial transition previously developed is being designed for use at the top of the mast where the connection is made to the antenna.

The high band 50 ohm pressure window mock-up has been assembled and tested. The maximum VSWR obtained over the high frequency band is 1.40. A larger 70 ohm version of this window was built and tested for use over the low band. Its maximum VSWR from 2.0 to 5.0 Gc/s was 1.20. However, the high band mock-up was also tested over this range, and its maximum VSWR was 1.36. Therefore, the use of two separate window designs to cover the two bands will be avoided by using the small version over both frequency bands.

ABSTRACT (cont.)

The movable mast design approach has been changed from the fixed two-position scheme to a continuously operating system useable over a six foot range of elevation. Considerable mechanical design work is required to accomplish this, and preliminary work is underway.

Revision 2 of the Milestone/Cost Plan is included in the report. This latest revision is a result of the change in scope of the movable mast approach, and it reflects the extra cost and time involved.

PURPOSE OF THIS CONTRACT

The development program covered by this report is an extension of work completed at Airtron under Contract Number NObsr - 72809, Index Number NE-071200, sponsored by the Electronics Divisions of the Bureau of Ships. The above contract proved the feasibility of replacing the coaxial cables used as transmission lines in the 2.3 to 10.75 Gc/s frequency bands with low-loss, double ridged waveguide transmission lines. The transmission line system developed was installed in the ECM mast of the U.S.S. Hardhead, and proved to be far superior in performance to the standard coaxial cable transmission line system.

The present contract is concerned with developing an improved system suitable for production, with emphasis on the following four areas:

1. Further reduction of insertion loss by at least 1.0 db as a target figure.
2. Reduction in weight without impairing performance.
3. Ease of installation in the submarine.
4. Incorporate a provision which will permit the antenna to be continuously operable from its uppermost elevated position down to a position 6 feet below that level.

GENERAL FACTUAL DATA

1. Identification of Technicians

This work is being carried on under the general supervision of Dr. Ernest Wantuch, Airtron Vice-President and Director of Engineering.

The following personnel performed work on this contract in the period covered by this report:

A.	Edward S. Hensperger	-	Project Manager	240.5 hours
B.	Walter D. Wagner	-	Electronics Engineer	279.0 hours
C.	Bernard Donnerstag	-	Mechanical Engineer	246.0 hours
D.	George Papczun	-	Mechanical Engineer (Switches)	30.0 hours
E.	John Walsh	-	Engineering Product Manager (Switches)	20.0 hours

DETAIL FACTUAL DATA

1. **Procurement of ALB-134 Ridged Waveguide**

   Some difficulty was encountered in locating a suitable vendor for the necessary amount of ALB-134 waveguide. As a result, the purchase order was issued late in December, approximately one month behind schedule. The order was given to Standard Metals Corporation, North Attleboro, Massachusetts, and delivery was promised in 10 to 12 weeks.

2. **Procurement of Optimum Size Splinaline**

   As indicated in the last interim report, an order for 90 feet of Splinaline was placed with Precision Tube Corporation, North Wales, Pennsylvania, for delivery early in December. Due to some tooling problems, delivery of the splinaline has not yet been made, which has resulted in certain delays in the Airtron development program plotted on the last Milestone/Cost Plan.

   Every effort is being made to expedite delivery of this material.

3. **Coaxial-to-ALB-134 Transition Design**

   The development of the new right angle transition was completed during the last period. However, it was determined at that time that an "end fire" version would also be needed at the top

DETAIL FACTUAL DATA

3. Coaxial-to-ALB-134 Transition Design (cont.)

of the mast for connection to an antenna. Design work on this version was done using two approaches. The first approach utilized an abrupt 90° turn with a built-in broad band stub. This approach was tried primarily because of its compactness. However, the resulting VSWR over the high frequency band was as high as 2:1, and therefore, this approach was dropped. Although the use of a radius type coaxial bend is less compact, it was felt that its relatively low VSWR would make its use worthwhile. Therefore, the second approach consists of a 1" radius bend attached to the right angle version of the adapter to yield the "end fire" configuration. This bend is presently being fabricated in the Shop.

Figure 1 in the Supplementary Data shows a plot of VSWR versus Frequency with the right angle ALB-134 adaptor connected in series with the high band pressure seal mockup described in the last report. This arrangement will be used in the actual installation, and as shown, the composite VSWR does not exceed 1.4.

DETAIL FACTUAL DATA

4. Pressure Window Design

The high band 50 ohm pressure seal mockup described in the last report was assembled and tested during this period. The physical dimensions of the unit are as shown in the sketches appended to the last report. Using Type "N" connectors, the VSWR obtained over the high frequency band is plotted in Figure 2. It is interesting to note that the maximum VSWR is 1.4 with or without the ALB-134 transition in series, (as plotted in Figure 1). Of course, the shape of the two curves differ, but the maxima are approximately the same.

It was also indicated in the last report that the small, 50 ohm, high band seal would be used for the low band as well. Before being committed to this approach, a larger 70 ohm version of the pressure seal was fabricated using the same taper function for use over the low band. The results obtained with this version and the 50 ohm high band version over the 2.0 to 5.0 Gc/s frequency band are plotted in Figure 3. Surprisingly enough, the high band seal yielded a slightly better VSWR (1.36 maximum) than it did over the high band. The 70 ohm low band design performed considerably better, which was to be expected due to size

4. Pressure Window Design (cont.)

considerations. Its maximum VSWR was only 1.20.

Since the high band seal performed so well over the low frequency band, it appears that its use for both bands is feasible and definitely advantageous from a simplicity and stocking point of view. Therefore, it is felt that this is the best choice.

Some preliminary insertion loss measurements were made on both pressure seal mockups. Their measurements are considered preliminary because the dielectric in the mockups is Stycast and not the low loss glass to be used in the final versions. In any case, the relatively high insertion loss figures seem to indicate that the Kovar center conductor (drill rod in the mockups) may present a problem. This area will be investigated fully during the next period, and appropriate action taken.

5. Change in Scope in Movable Mast

In the last report, it was stated that a decision was made to confine the development approach on the movable mast to a two position mast utilizing switches and a four foot spacing between the two positions. The developmental effort, therefore, was directed

5. Change in Scope in Movable Mast (cont.)

along these lines until a telegram was received from BuShips on December 15, 1962 that instructed Airtron to abandon this approach and change to a continuously operating mast, operable over a range of 6 feet in elevation.

This decision obsoleted some of the work that had been done up to this time, but not a great amount. The most significant change in the program was the elimination of the development and fabrication of the two coaxial switches which were to connect the two mast positions to the tuner. Fortunately, developmental work on the switches had begun on December 1, and consequently, only two weeks of effort was lost in this area.

Some useable design information resulted from the two position mast effort during the period before the change in scope. During this last period, a mechanical engineer was assigned full time to the task of studying the coupling mechanism problems and coming up with the necessary preliminary design approaches. One of the most difficult problems relating to the coupling plate assembly is the "make and break" connection between the coaxial

5. Change in Scope in Movable Mast (cont.)

lines coming out of the mast to the coaxial lines in the plate. Most of the preliminary design effort during this last period was applied to this problem, and the change in scope did not affect this seriously.

Essentially, the connections between the coaxial lines at the coupling plate are made by spring loaded center conductors on the coupling plate side which mate with the center conductors coming through the mast. The coaxial lines on both sides are solid dielectric filled to provide the necessary mechanical support and rigidity. This type of connection should be practically lossless since most of the current in a coaxial line is carried on the surfaces of the center conductor. Careful attention has been paid to simplicity of design, as well as ease of installation and replacement. As indicated, this design work is only in the preliminary stages and drawings, etc. are not yet available.

A theoretical insertion loss evaluation of various approaches to the movable mast problem was made in the last report. The

5. Change in Scope in Movable Mast (cont.)

losses tabulated covered only the attenuation added to the basic line contained within the mast itself. In other words, these loss figures represented the theoretical attenuation from the coupling plate connections to the tuner. The present continuously operating mast condition was covered in Section 3. b. of the Detail Factual Data for a four foot operating range. The losses for the four foot scheme were 2.0 db at 10.0 Gc/s, and 0.5 db at 2.0 Gc/s. This analysis assumed that a fixed point halfway between the two extremes of the coupling position was connected to the sliding coupling plate with 3 feet of RG-9/U flexible cable, and the tuner was connected to the fixed point with 3 feet of low loss splinaline, (1/2" splinaline for the high band, and the optimum splinaline for the low band). To bring this evaluation up-to-date with the six foot operating mast, the line lengths would have to be changed to 4 feet of flexible cable, and 4 feet of low loss splinaline to the tuner. The actual value of the splinaline length in a given submarine installation may be more or less, depending upon location of the tuner. Under these conditions, the attenuation loss between the coupling plate and the tuner becomes 2.32 db at 10.0 Gc/s

5. Change in Scope in Movable Mast (cont.)

and 0.64 db at 2.0 Gc/s. The increase in loss due to the extra Splinaline is almost negligible. It is the RG-9/U cable which contributes most of the loss, (0.14 db/ft. at 2.0 Gc/s and 0.44 db/ft. at 10.0 Gc/s). However, the connection between the fixed point and the sliding coupling plate must be flexible and rugged enough to stand the constant flexing required as the mast is moved up and down. It is hoped that a flexible cable can be found for this application that is similar mechanically to RG-9/U but with lower attenuation characteristics. An investigation of flexible coaxial cables for this purpose is underway.

At this point in the development, the setup to be used to accomplish the continuously operating mast requested, is visualized to be as shown in Figure 4. In this sketch, the dotted outline of the bottom of the mast represents the lowest engaged position of the mast, while the full detailed portion represents the uppermost position, six feet above the lowest position. The coupling plate assembly will ride on guide rails (not shown in sketch) over the required six feet of travel. This arrangement will work in the following fashion: the coupling plate, when disengaged, will

5. Change in Scope in Movable Mast (cont.)

be in the lower position. As the mast is brought up hydraulicly for use, the bottom mating portion of the mast will engage with the coupling plate and lock in. The coupling plate will then continue to travel with the mast, and it will remain locked in, ready for use, anywhere within the six foot range of travel. When the mast is brought down, the coupling plate will automatically disengage as the mast passes the lowest operating position, and the mast will continue down until it is fully retracted.

The operating principles described above are quite straight forward. However, to realize a foolproof, rugged design, several mechanical complications must be overcome. For instance, the guide rails have to be held in place very accurately and must be rugged enough to retain their exact shape under stress. The coupling plate assembly riding on these rails must use special ball-bushings as bearing surfaces. A mechanism must be designed to automatically engage and disengage the coupling plate assembly, and this mechanism must provide for holding the coupling plate assembly fixed in

5. Change in Scope in Movable Mast (cont.)

place while engagement is taking place. Shock mounts must also be provided to take up some of the force on the coupling plate assembly when it bottoms as the mast is coming down. Therefore, the design work to accomplish all these features in a practical and simple to maintain assembly is quite extensive.

6. Revised Milestone/Cost Plan (Revision 2)

Revision 2 of the Milestone/Cost Plan is appended to this report. Fairly extensive changes have been made in this plan to reflect the change in scope discussed above. The changes are summarized below:

A. The milestone covering the coaxial switch design and fabrication has been eliminated.

B. The milestones covering the two position mast have been revised and expanded into more phases due to the additional work involved.

C. The length of the program has been changed from 12 months to 15 months to reflect the additional time required to

DETAIL FACTUAL DATA

6. Revised Milestone/Cost Plan (Revision 2) -cont. -

C. accomplish the extra work and to account for the delay in delivery of the ordered transmission lines. Originally, the program was scheduled for 18 months, but this was moved back to 12 months. Now it appears that a 15 month program is the realistic choice.

D. The contract price has been revised on the plan to agree with the requested additional funds required to cover the change of scope in the movable mast.

CONCLUSIONS

The ALB-134 ridge waveguide ordered from Standard Metals is scheduled for delivery at the end of March, 1963. This delivery date, if met, will allow a period of one month before fabrication of the necessary line sections begins according to the Milestone schedule.

The Splinaline on order from Precision Tube Corporation is overdue on delivery, and this fact has resulted in some delays in designing connectors and transitions. Therefore, this situation has contributed to the need for an extension of the contract completion from June to September.

To come up with a compact end-fire transition from ALB-134-to-Type N, a short stub right angle turn was tried. However, this approach yielded a mismatch higher than that desired. Therefore, to effect this right angle turn, a 1" radius 90° coaxial bend will be attached to the right angle ALB-134 adaptor.

The evaluation of the high and low band pressure window mock-ups showed that it is feasible to use the small high band version over both the 2.0 to 5.0 Gc/s and 5.0 to 10.75 Gc/s frequency bands. This approach will simplify the overall assembly and result in a lower production cost.

CONCLUSIONS (cont.)

It appears that the insertion loss of a Kovar center conductor in the window is considerably higher than can be tolerated. Therefore, a full investigation into this problem and its solution is presently underway.

The BuShips request to change the two position mast approach to a continuously operating setup has necessitated a complete revision of the Milestone/Cost Plan and the schedule for completion of the contract. This change has resulted in a more versatile mast positioning scheme, but it has complicated the mechanical design of the movable mast, with the result that more mechanical design effort and time is required to accomplish the desired arrangement.

PROGRAM FOR NEXT INTERVAL

The new Milestone/Cost Plan outlines the schedule for the work to be accomplished during the next period. A brief summary appears below:

A. Complete the design and fabrication of the end-fire version of the ALB-134-to-coaxial adaptor.

B. Complete the preliminary mechanical and electrical design of the coupling plate and rail assembly for the movable mast, and breadboard this design. When breadboarding is complete, finalizing the design and life testing will be started.

C. Complete the design of the pressure windows.

D. Design the necessary 50 ohm Type "N" to 70 ohm Splinaline transitions for use in coupling to the tuner.

In addition, the ALB-134 ridge waveguide on order should be delivered late in March. The Splinaline on order, which is overdue, should also be delivered during this period, and every effort will be made to expedite this for earliest possible delivery. Also, every effort will be made to locate a low loss flexible cable for the flexible line connection between the coupling plate assembly and the transitions to the 70 ohm Splinaline to the tuner.

SUPPLEMENTARY DATA

Appended to this report are the following:

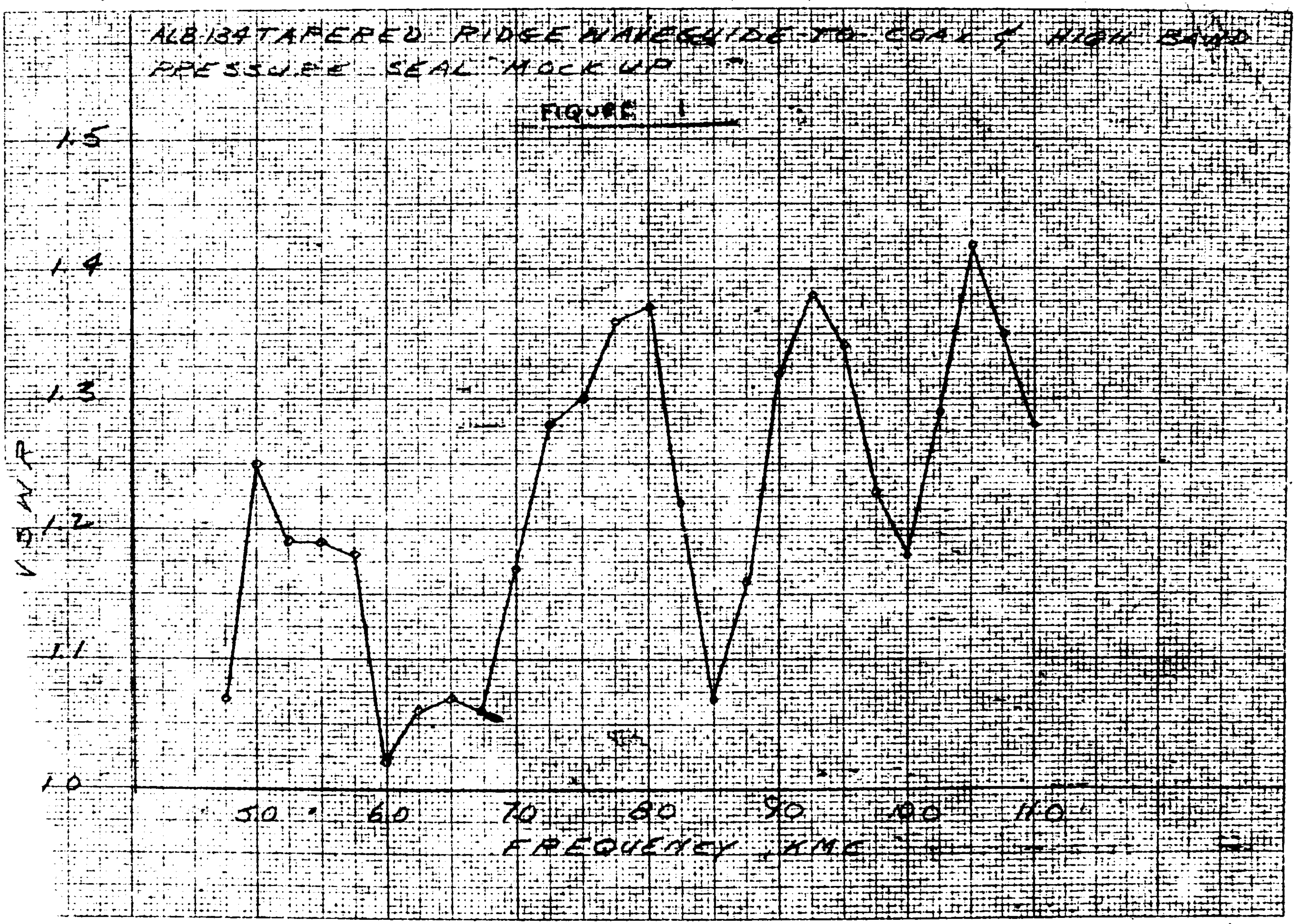
1. FIGURE 1: VSWR vs. Frequency - ALB-134 Transition and High Band Pressure Seal Mock-Up.

2. FIGURE 2: VSWR vs. Frequency - High Band Pressure Seal Mock-Up.

3. FIGURE 3: VSWR vs. Frequency - High and Low Band Pressure Seal Mock-Ups over the Low Frequency Band.

4. FIGURE 4: Sketch of Continuously Operating Mast Setup.

5. Milestone/Cost Plan (Revision 2)


ALB 134 TAPERED RIDGE WAVEGUIDE TO COAX HIGH BAND
PRESSURE SEAL MOCK UP
FIGURE 1
1.5
1.4
1.3
1.2
1.1
1.0
VSWR
50
60
70
80
90
100
110
FREQUENCY, KMC

NO. 340-20 DIETZGEN GRAPH PAPER
20 X 20 PER INCH

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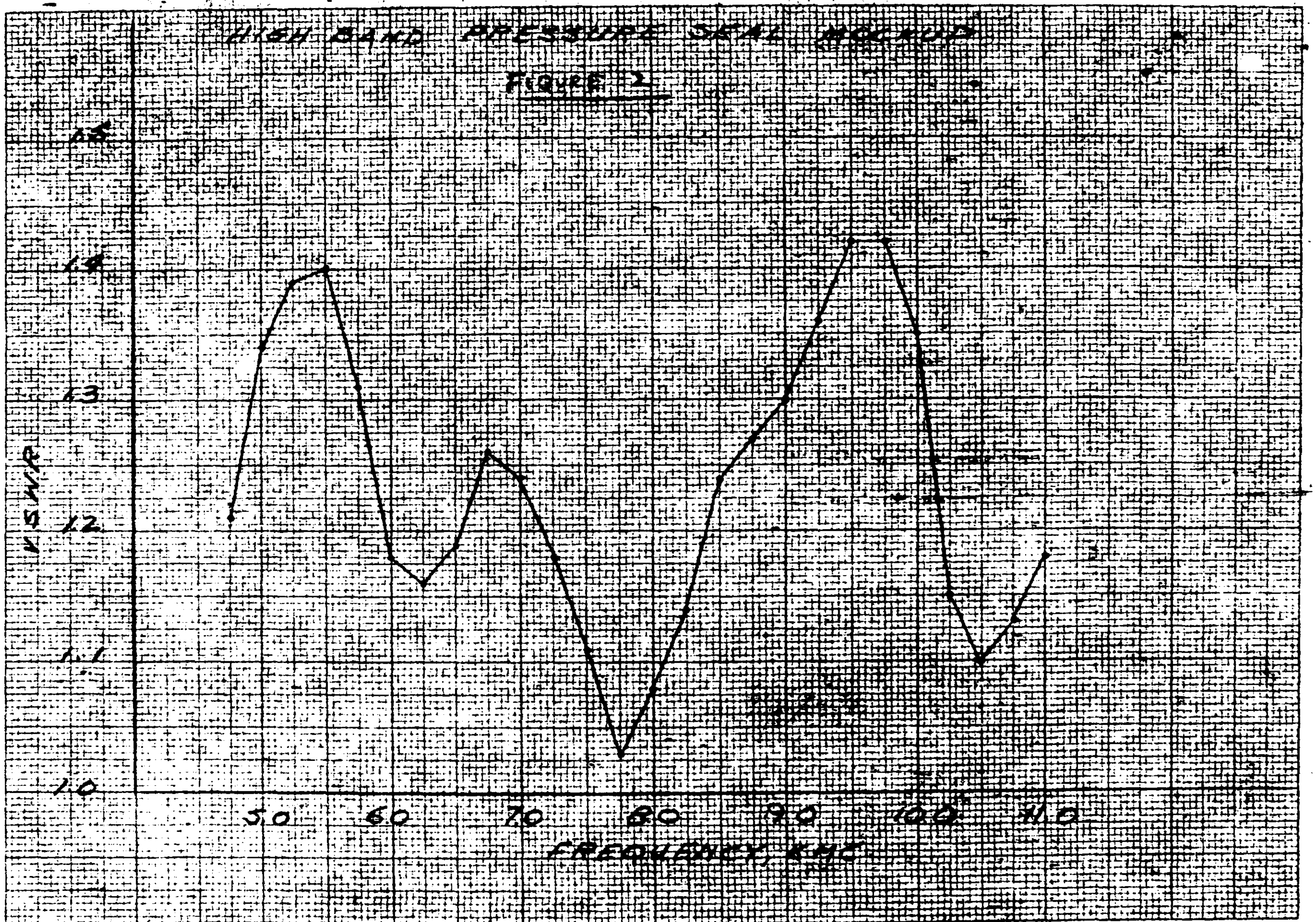

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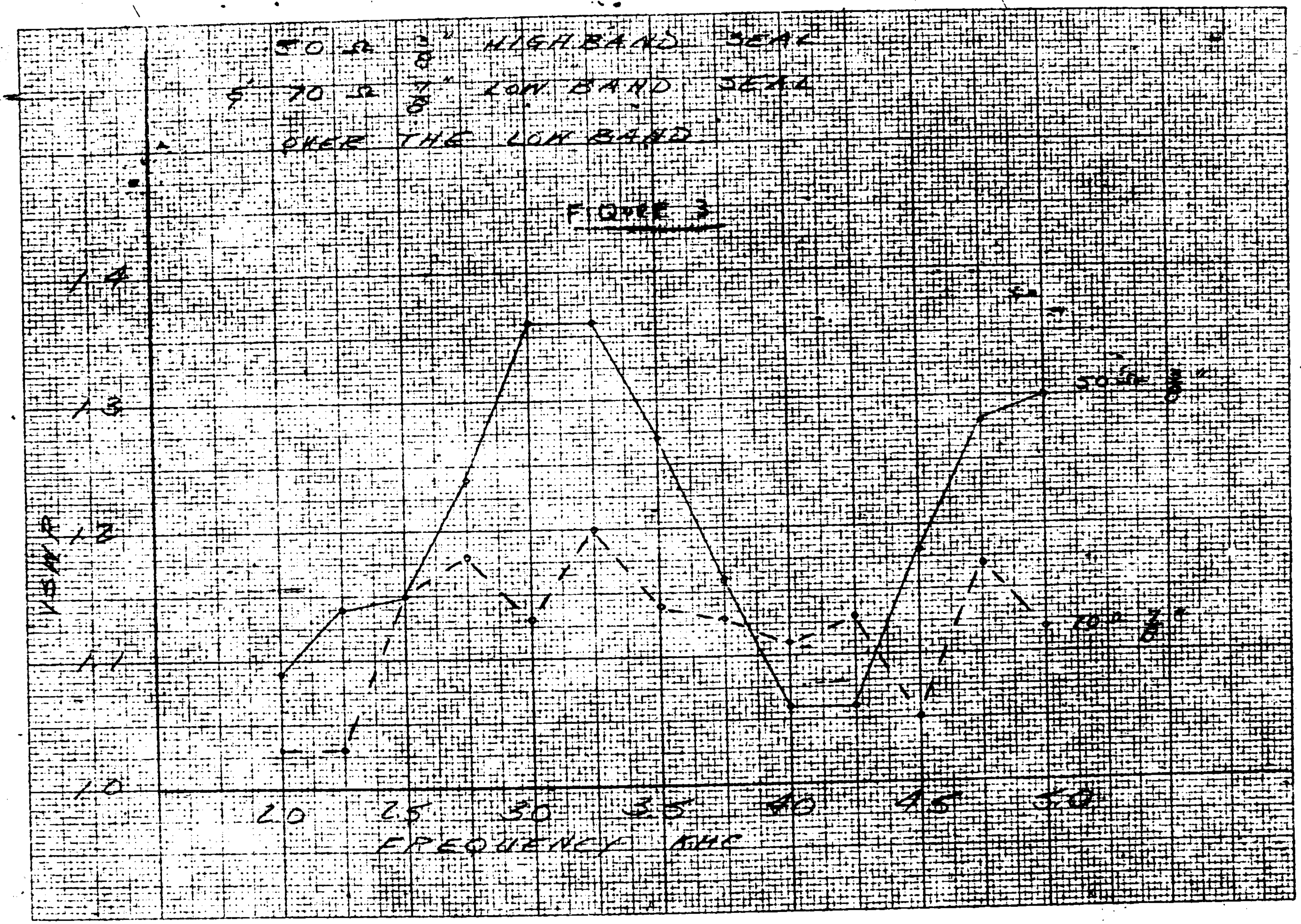
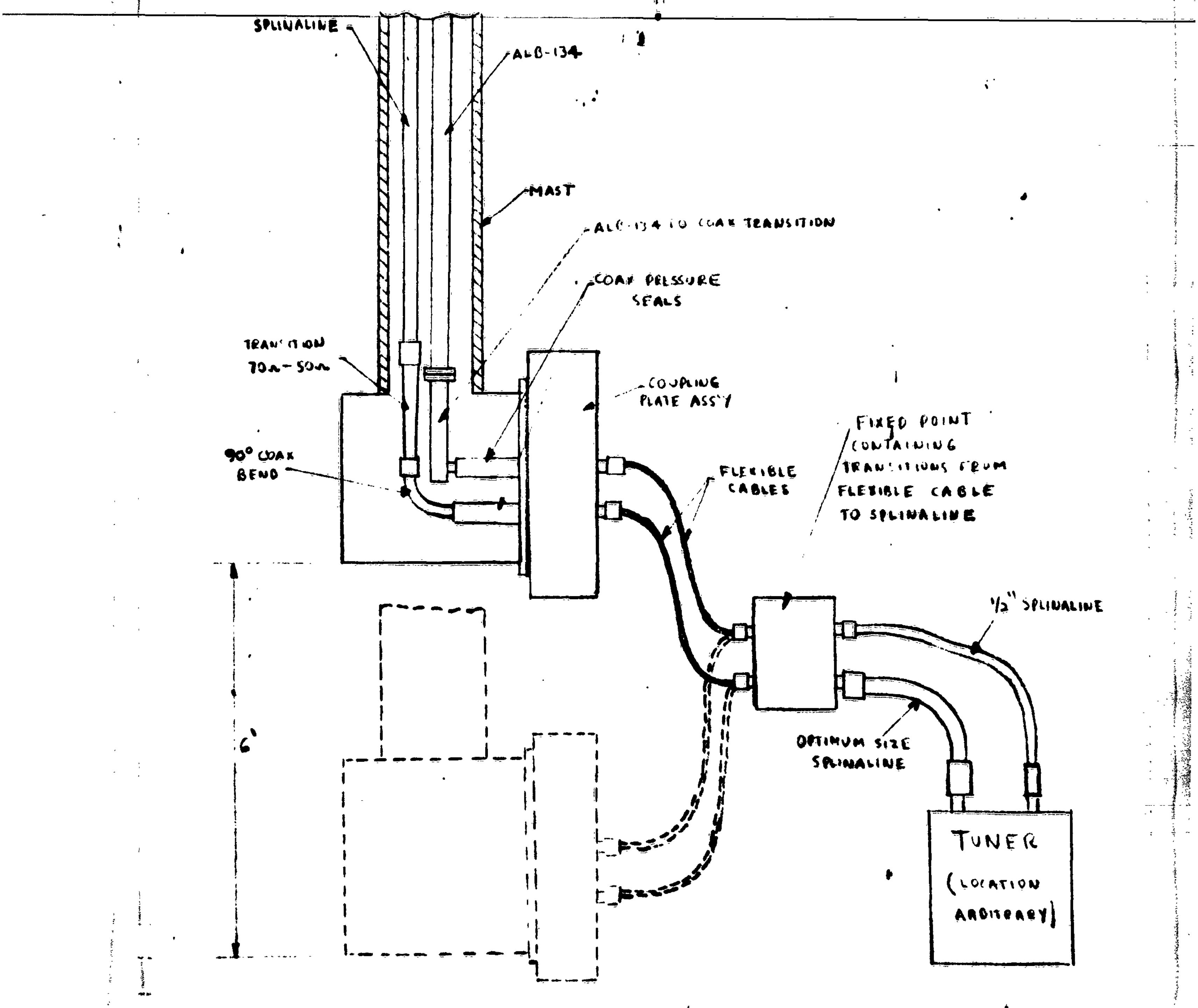


SKETCH OF CONTINUOUSLY OPERATING MAST SET UP

FIGURE 4



Airtron, Inc.
SO-524801-CP

MILESTONE/COST PLAN
FOR
SUBMARINE MAST PROGRAM
CONTRACT NOBSR--87676

Revision 2

1. **Key to Milestones**

1 — Repair of previously developed system installed on U.S.S. Hardhead (added to original contract).

2 — Study to determine actual coaxial line configuration and type for low band run and placing order for material.

3 — Study to determine configuration and type of ridged waveguide line for high band run and placing order for material.

4 — Study of movable mast problem and determination of approach.

5 — Design, fabrication, and test of new coaxial-to-ridged waveguide adaptor, (2 versions).

6 — Preliminary design and breadboarding of coupling plate and rail assembly.

7 — Design, fabrication, and test of pressure windows and associated adaptors to coaxial line.

8 — Design of 50 ohm to 70 ohm coaxial line transitions. (2 sizes)

9 — Finalizing design and life testing of coupling plate and rail assembly.

10 — Qualification testing of pressure windows.

11 — Fabrication of connecting transmission line sections and procurement of hardware.

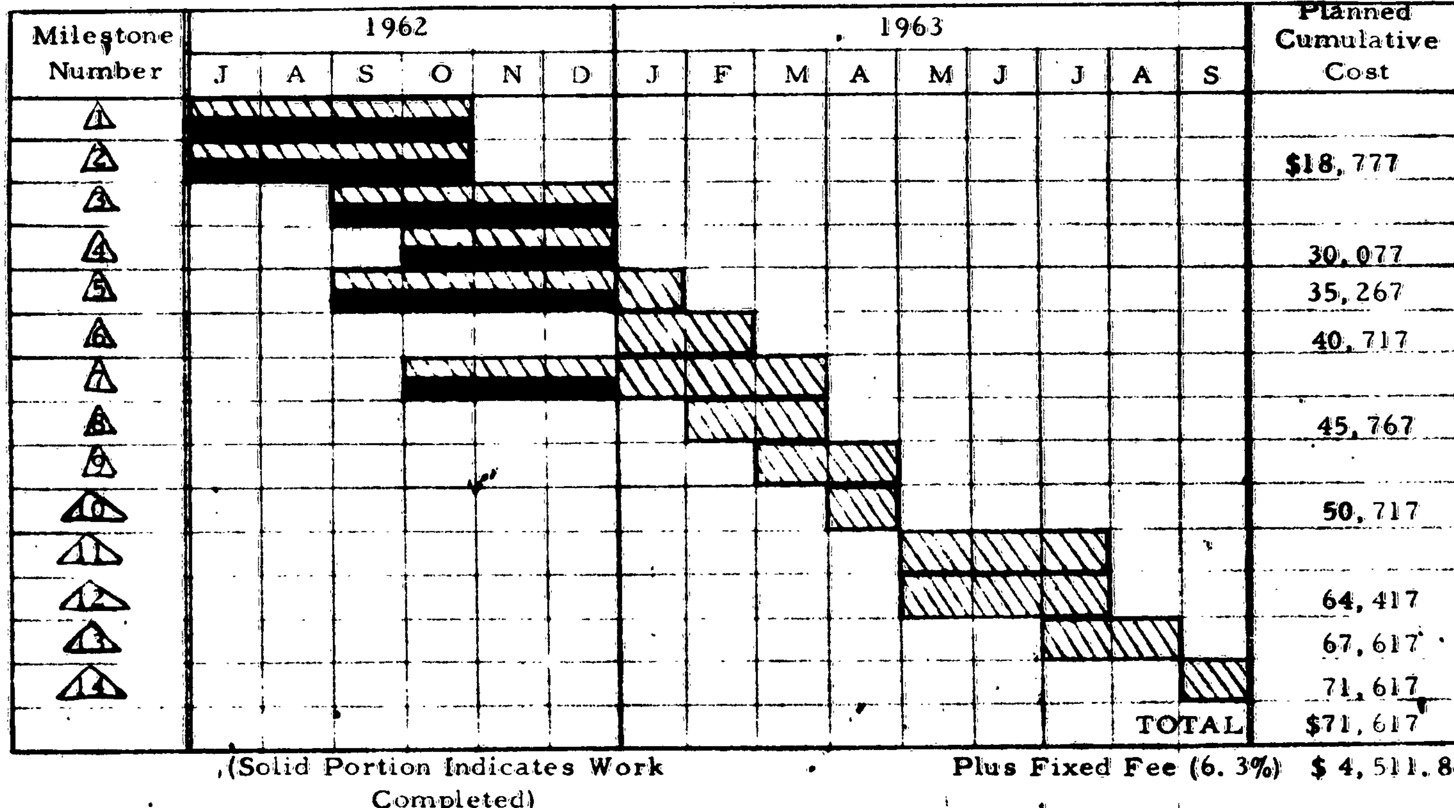
12 — Fabrication of complete coupling plate and rail assembly.

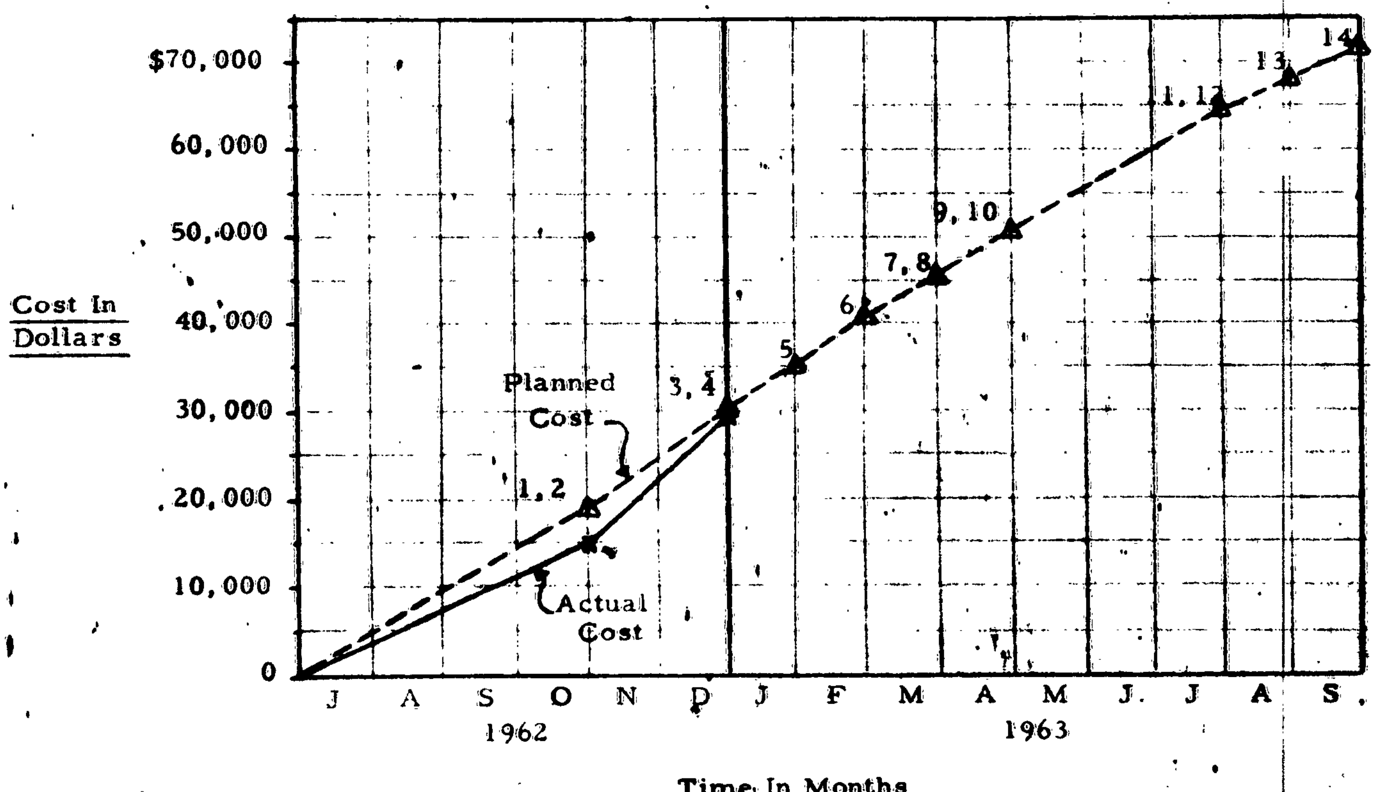
13 — Final assembly, testing, and shipment.

14 — Assistance and guidance in submarine installation and final report.

2. **Forecasted Achievement Date and Cumulative Cost**

Milestone Number	1962						1963									Planned Cumulative Cost
	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	
1																
2																$18,777
3																
4																30,077
5																35,267


Milestone Number
1962
1963
J
A
S
O
N
D
J
F
M
A
M
J
J
A
S
Planned Cumulative Cost
1
2
3
4
5
6
7
8
9
10
11
12
13
14
$18,777
30,077
35,267
40,717
45,767
50,717
64,417
67,617
71,617
TOTAL
$71,617
(Solid Portion Indicates Work Completed)
Plus Fixed Fee (6.3%)
$ 4,511.87


Cost In Dollars
$70,000
60,000
50,000
40,000
30,000
20,000
10,000
0
Planned Cost
Actual Cost
1, 2
3, 4
5
6
7, 8
9, 10
11, 12
13
14
J
A
S
O
N
D
J
F
M
A
M
J
J
A
S
1962
1963
Time In Months

2